Danfoss - Aftermarket Workflow and Process Creation and Implementation

Team:504

Team Introductions

David Bishop
System Engineer

Alex Wilson
Design Engineer

Kyle Youmans
Design Engineer

Julian Villamil
System Engineer

David Bishop

Sponsor and Advisor

Engineering Mentor
Shayne McConomy, Ph.D
Professor

Project Advisor
Yousuf Ali, Ph.D.
Professor

Engineering Mentor
Stephen Seymore
Operations Engineer Director

David Bishop

Project Objective

"The objective of this project is to design an integrated system that generates a bill of materials for a given aftermarket compressor using records provided by Danfoss's investigation team"

David Bishop

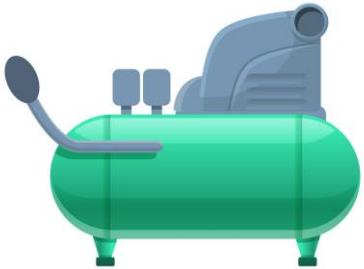
Project Background

David Bishop

What's the Process?

Where we come in

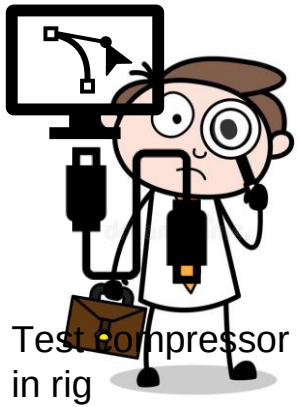
Receive Compressor | Inspection | Planning | Production | Pack & Ship



David Bishop

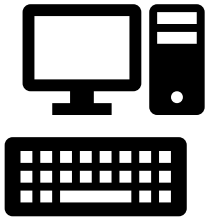
What's the Process?

Receive Compressor | **Inspection** | Planning | Production | Pack & Ship

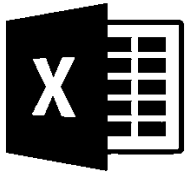


- Test compressor in rig
- Receive pass or fail feedback

- Disassemble
- Inspect each part for flaws and obsolescence



- Log report into Cool Inspector
- Model, part and serial numbers



- Export excel file to planning

David Bishop

What's the Process?

Receive Compressor | Inspection | **Planning** | Production | Pack & Ship

- Planne
  excel fi
- Determ
  failed

- Find appropriate replacement part
- Produce bill of materials

- Send B.O.M. to production

David Bishop

Problems

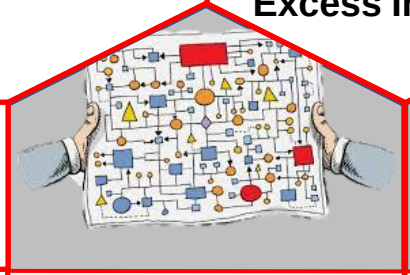
Duplicate items and wrong orders

Over Production and Excess Inventory

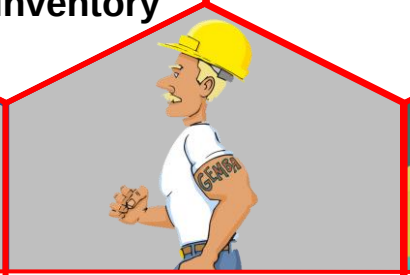
Defects

Returning failed and obsolete parts to production

Trying to interpret inspection report



Over-Process



Wasted Motion

Wasted Talent

Using skilled technicians for a simple task

Inspection to planning and vice versa

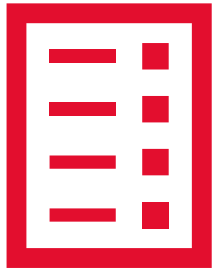
David Bishop

Solution

Investigation Report
File .xlsx

Obsolescence File
.xlsx

MATLAB Script



Bill of Materials

David Bishop

Input Files

Kyle Youmans

Investigation Failure Report

- Exported from SAP software Cool Inspector
- Contains 287 columns of investigations information
- Part replacement decisions made using this file
- Contains multiple compressor cases sorted by serial number

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
1	Manufa	Compr	Platfor	Applica	Claim Number	Model No	Serial No	Customer Na	Inspect	IC/IQC	Compr	IC Repo	Manufa	Record	0-6 Mo	Case C	Produc	Custon	Custon	Reason	Reason	Status	Registe
2	DTC Talla	TT/TG		0	8550074469	TT350-G6-1-HL-E-0-NC	140295010	Multistack LLC	DTC FIC	11/4/2020	11/4/2020	11/4/2020	1/29/2014	No	No	Field Retu	0	USA		0	TS350E REPAIR_	In-Progre	Kevin Doc
3	DTC Talla	TT/TG		0	8550074888-8590544877	TT700-G-1-ST-F-O-NC	1930850007	Daikin Applied	DTC FIC	11/3/2020	11/2/2020	11/3/2020	11/4/2019	Yes	No	Field Retu	0	USA		0	Compress	In-Progre	Kevin Doc
4	DTC Talla	TT/TG		0	8550074832	TT300-G-1-ST-E-O-NC	151815040	Smardt Montrea	DTC FIC	11/2/2020	########	11/2/2020	6/30/2015	No	No	Field Retu	0	CANADA		0	Eval & Re	In-Progre	Kevin Doc

	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP	AQ	AR	AS	AT	AU	AV	AW	AX	AY
	Summi	Approv	picture	Boards	Compr	Compr	DTCPa	Comm	Compr	Specify	Numbe	SoftSta	SoftSta	SoftSta	DCDC	DCDC	DCDC	BackPl	BackPl	BackPl	SerialD	SerialD	SerialD	BMCC	BMCC	BMCC	PWM_	PWM_
	dson																											
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Kyle Youmans

Obsolescence File

ENGINEERING TOMORROW

Component	Part Number(s)	Revisions Affected	Specification	Affected Range	Reason
IGBT Inverter (SKiiP 513)	390032	All	Inverter should run full life expectancy at all acceptable operating conditions.	All TT350, TT400, & TT500 Compressors built before May 2012	The SKiiP 513 is not as robust as the SKiiP 613 and has shown a higher early failure rate.
Softstart	220135, 220136, 220137, 220138, 224000, 224001, 224002, 224003, 224004-1, 224004-2, 224004-3, 224004-4	All	All revisions should be replaced with 200193.	All models	200193 functions with every voltage, thus eliminating the need to maintain multiple softstarts while improving reliability.
DC/DC	340029, 342029, 370029, 380029	All	All revisions should be replaced with 300287.	All models	The earlier DC/DC revisions do not selfprotect in the event of an output short and, in the case of the TT350, do not have sufficient power to support the axial bearing in the event of a high pressure ratio shutdown. These two problems have been addressed in the redesigned 300287.
Backplane	200125	Pre Rev K	All revisions prior to Rev K should be replaced.	All models	Revisions prior to rev K should be replaced due the lower reliability of certain capacitors which were marginally rated.
Serial Driver	300047	Pre Rev G	All revisions prior to Rev G should be replaced.	All models	All revisions prior to Rev G utilized mechanical relays for the cooling solenoid control circuit which could wear out prematurely leading to overcooling. These have been replaced with solid state relays.
BMCC	300046	Pre Rev L	All revisions prior to Rev L should be replaced.	All models	Revisions prior to Rev L contained less actuate P/T sensor circuits leading to excessive variation in sensor reading.

Kyle Youmans

Determining Obsolescence

ENGINEERING TOMORROW

Component	Part Number(s)	Revisions Affected	Specification	Affected Range	Reason
IGBT Inverter (SKiiP 513)	390032	All	Inverter should run full life expectancy at all acceptable operating conditions.	All TT350, TT400, & TT500 Compressors built before May 2012	The SKiiP 513 is not as robust as the SKiiP 613 and has shown a higher early failure rate.

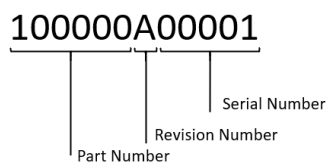
- Parts are considered obsolete after considerable time has passed
- Determined by either date or revision number
- Script compares today's date with the manufactured date
- Script determines obsolescence by ensuring that the model in question is one of the models listed in the affected range

Manufacture Date
1/29/2014
11/4/2019
6/30/2015
12/13/2011
10/30/2020
7/10/2015
10/29/2010
4/22/2019
10/28/2020

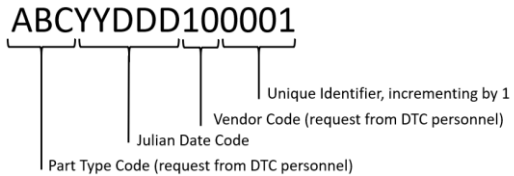
Kyle Youmans

Decoding Serial Numbers

- Danfoss has two versions of serial number: an old and a new



Old Serial Number

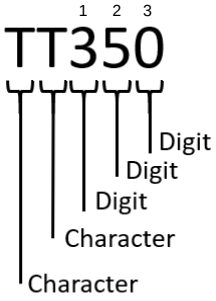


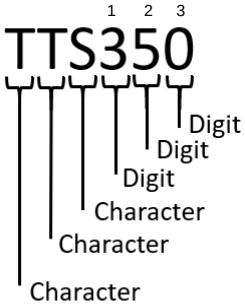
New Serial Number

- The old serial numbers can be used to capture the revision number
- The new serial numbers capture the date
- Now we separate logic for each serial number: old and new.
- This information can be extracted and decoded in MATLAB to determine obsolescence for a given part number.
- This can then be used to generate a bill of materials

Decoding Compressor Model Information

- The compressor model number comes in from the input file as a string of letters and numbers
- The highlighted text is the information that needs to be extracted from the file.
- This will be done by extracting characters from the string until the character in question is equal to a digit.
- Then the script will extract three characters after that.





Type of Compressor

Voltage

Rev

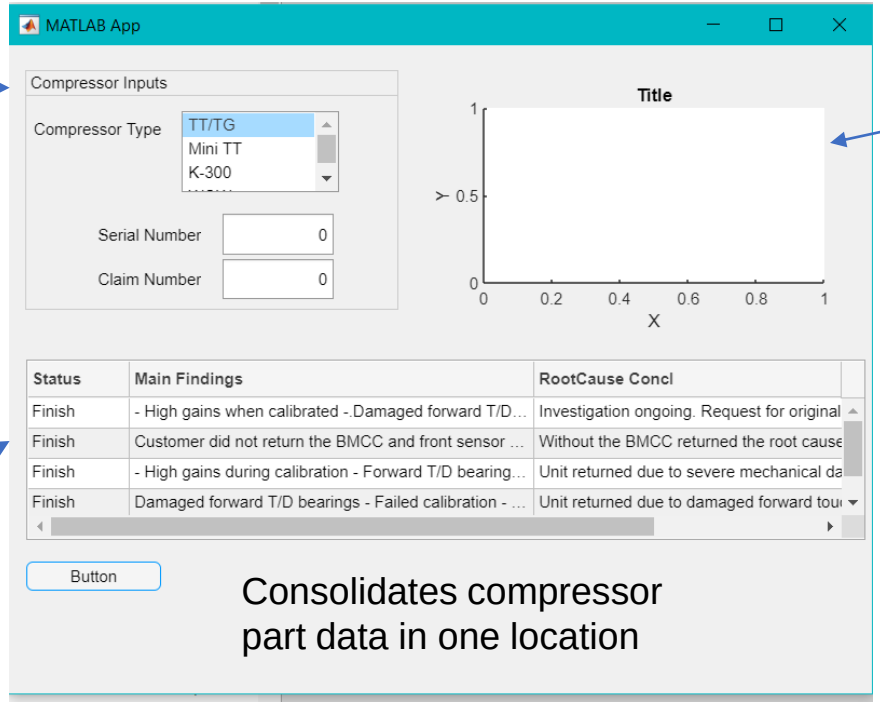
New Version

Model No
TT350-G6-1-HL-E-0-NC
TT700-G-1-ST-F-O-NC
TT300-G-1-ST-E-O-NC
TT300-G7-1-ST-E-0-NC
TT350-E-1-ST-F-O-CH
TT300-H6-1-ST-E-O-CE
TT350-E-1-ST-F-O-CH
TT350-H-1-ST-F-O-CE
TT350-E-1-ST-F-O-CH
TTS350HES1S020X0XXS352

Kyle Youmans

MATLAB Designer App GUI Template

System Inputs



Metrics

Decision Making Output

Consolidates compressor part data in one location

Kyle Youmans

Looking Forward

Kyle Youmans

Future Challenges

Continual Script Maintenance

Team will create a tutorial/user manual for the app.

Older vs Newer Serial Number Format

Team will find an alternative method for gathering serial information.

Danfoss Moves Away from SAP

Team will create a new data management strategy.

Kyle Youmans

Future Work

- Determine what data from our input file is relevant
- Begin making a prototype given the current relevant data
- Construct an updatable obsolescence input file
- Meet with Ashley Daniels, a planner at Danfoss who will show us her role as a material handler

Reference

[1] Seymore, Stephen. (2020). Aftermarket Services Danfoss Turbocor® Compressors. [PowerPoint slides]. Retrieved from https://3.basecamp.com/3939307/buckets/18515621/uploads/3119943154

[2] McConomy, Shayne. (2020). Aftermarket Workflow Project 2020. [Word document]. Retrieved from https://3.basecamp.com/3939307/buckets/18515621/uploads/3078752695

[3] Bishop et al. (2020). SD T504 201106 Concept Generation and Selection. [Word document]. Retrieved from https://famu-fsu-eng.instructure.com/courses/4476/assignments/18861/submissions/102840000000061346

[4] Seymore, Stephen. (2020). Special Compressor Process. Danfoss Turbocor®. [PDF file]. Retrieved from https://3.basecamp.com/3939307/buckets/18515621/uploads/3119943196

Questions?

Backup Slides

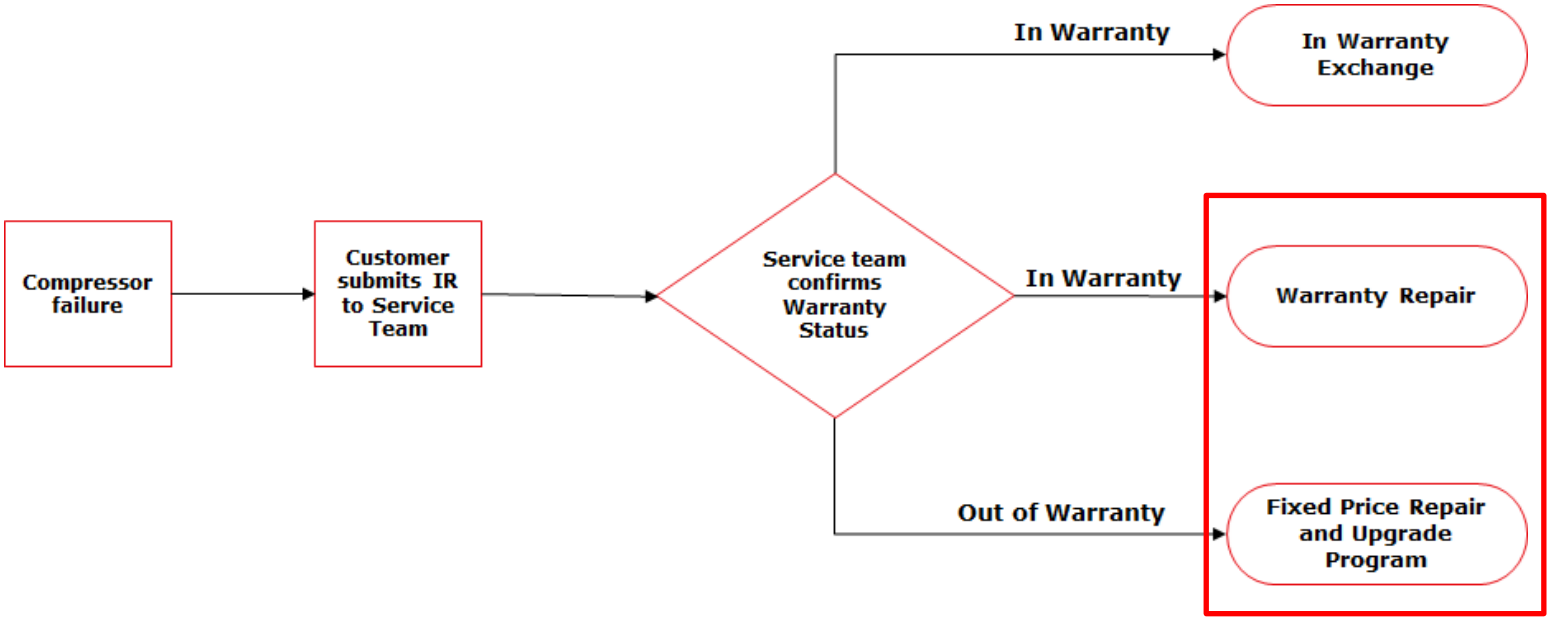
Scanner System

300138:ABCYYDDD100001

Part Number Serial Number

- Danfoss has a current scanning system
- Danfoss also has a quality control department

Future Aftermarket Repair Programs



David Bishop

Morphological Chart

Morphological Chart			
Coding Language	Python	MATLAB	C
Quality Control Method	Pareto Analysis	Stratification	Statistical Sampling
Inventory Control Method	Six Sigma	Drop shipping	Lean Manufacturing

Binary Pairwise

Binary Pairwise Graph

	1	2	3	4	5	Total
1. Organization	-	1	1	1	1	4
2. Automate	0	-	1	1	1	3
3.Quality Control	0	0	-	1	1	2
4. User Experience	0	0	0	-	0	0
5. Adaptability	0	0	0	1	-	1
Total	**0**	**1**	**2**	**4**	**3**	**10**

House of Quality

House of Quality									
		Engineering Characteristics							
Improvement Direction		↑	↑	↑	↑	↑	↑	↑	↓
	Units	sec	byte	%	n/a	n/a	n/a	n/a	%
Customer Requirements	Importance Weight Factor	Speed	Storage Capacity	Accuracy	Usability	Aesthetic	Maintainability	Simplicity	Reliability
Organizes	5	1	3	9	1	1	3	1	9
Automate	4	1	0	1	9	0	9	1	3
Controls Quality	3	0	1	9	1	0	3	3	9
Interacts with User	2	0	1	1	9	9	0	3	1
Adaptible	1	0	3	1	9	1	9	3	3
Raw Score (391)		9	23	79	71	24	69	27	89
Relative Weight %		2.30%	5.88%	20.20%	18.16%	6.14%	17.65%	6.91%	22.76%
Rank Order		8	7	2	3	5	4	6	1

First Pugh Chart

Selection Criteria		Concepts							
		1	2	3	4	5	6	7	8
Speed	Datum (Current Method)	+	+	+	+	+	+	+	+
Storage Capacity		+	-	-	S	S	-	+	+
Accuracy		+	+	+	+	+	+	+	+
Usability		+	+	+	+	+	+	+	+
Aesthetic		+	+	+	S	+	+	+	+
Maintainability		+	+	+	+	+	+	+	+
Simplicity		+	-	-	+	+	+	+	+
Reliability		+	+	+	+	+	+	+	+
Pluses		8	6	6	6	7	7	8	8
Minuses		0	2	2	0	0	1	0	0

Second Pugh Chart

Selection Criteria		Concepts 1	4	6	7	8
Speed	Datum (Concept 5)	+	S	+	+	+
Storage Capacity		+	-	-	+	S
Accuracy		+	-	+	+	+
Usability		+	-	+	+	+
Aesthetic		+	-	+	+	+
Maintainability		+	-	+	+	+
Simplicity		+	-	+	+	+
Reliability		+	-	+	+	+
Pluses		8	0	7	8	7
Minuses		0	7	1	0	0

Third Pugh Chart

		Concepts		
Selection Criteria		1	6	8
Speed	Datum (Concept 7)	S	+	-
Storage Capacity		S	-	S
Accuracy		+	+	S
Usability		-	+	S
Aesthetic		S	S	S
Maintainability		-	+	+
Simplicity		+	-	+
Reliability		+	+	S
Pluses		3	5	2
Minuses		1	2	1

Target Catalog

Metric	Target
Storage Capacity	0 < x < 10 Megabytes
Ease of Use	Number of clicks by user 1
Aesthetic Appeal	1-5 (customer satisfaction survey) 5
Information Obtained to Total Information Needed	100%
Processing Speed	2 GHz to 4.0 GHz
File Conversion Accuracy	Files converted to files requested 100%
Data Format Accuracy	File matches column and row assigned Binary (1-0)
Part Conversion Efficiency	Ratio of parts exchanged correctly to total parts exchanged 100%
Reliability	Below 7% average failure rate
Code Complexity	1-5 (customer satisfaction survey) 5
File Location Accuracy	Files placed in the correct location Binary (1-0)
Organization	1-5 (customer satisfaction survey) 5

Customer Survey

Customer Satisfaction Survey					
Question 1 = unacceptable 2 = poor 3 = satisfactory 4 = good 5 = excellent	Order of Satisfaction				
	1	2	3	4	5
How aesthetically appealing is the display of the product?					
Is the code readable, organized, and reproducible?					
How does the product compare to the previously used method?					

AHP

Criteria Comparison Matrix [C]								
	Speed	Storage Capacity	Accuracy	Usability	Aesthetic	Maintainability	Compactness	Reliability
Speed	1	3	5	3	0.33	5	3	5
Storage Capacity	0.33	1	5	0.33	0.20	3	1	3
Accuracy	0.20	0.20	1	0.33	0.20	0.33	0.33	1
Usability	0.33	3	3	1	0.33	3	1	3
Aesthetic	3	5	5	3	1	5	5	5
Maintainability	0.20	0.33	3	0.33	0.20	1	0.33	1
Compactness	0.33	1	3	1	0.20	3	1	3
Reliability	0.20	0.33	1	0.33	0.20	1	0.33	1
Sum	5.60	13.87	26	9.33	2.67	21.33	12	22

Normalized Criteria Comparison Matrix									
	Speed	Storage Capacity	Accuracy	Usability	Aesthetic	Maintainability	Compactness	Reliability	Criteria Weight (W)
Speed	0.179	0.216	0.192	0.321	0.125	0.234	0.250	0.227	0.218
Storage Capacity	0.060	0.072	0.192	0.036	0.075	0.141	0.083	0.136	0.099
Accuracy	0.036	0.014	0.038	0.036	0.075	0.016	0.028	0.045	0.036
Usability	0.060	0.216	0.115	0.107	0.125	0.141	0.083	0.136	0.123
Aesthetic	0.536	0.361	0.192	0.321	0.375	0.234	0.417	0.227	0.333
Maintainability	0.036	0.024	0.115	0.036	0.075	0.047	0.028	0.045	0.051
Compactness	0.060	0.072	0.115	0.107	0.075	0.141	0.083	0.136	0.099
Reliability	0.036	0.024	0.038	0.036	0.075	0.047	0.028	0.045	0.041
Sum	1	1	1	1	1	1	1	1	1

AHP

Consistency Check		
{Ws}=[C]{W} Weighted Sum Factor	{W} Criteria Weights	Cons={Ws}./{W} Consistency Vector
1.932	0.218	8.854
0.834	0.099	8.393
0.298	0.036	8.274
1.087	0.123	8.841
2.986	0.333	8.969
0.417	0.051	8.221
0.844	0.099	8.553
0.345	0.041	8.391

λ=8.562
CI= (λ-n)/(n-1) = (8.562-8)/(8-1)=.0803
CR= CI/RI=.0803/1.4=.0574
CR < 0.1

AHP

Speed Comparison Norm				
	Script and Database	A.I.	Digital Library	Design Alternative Priorities
Script and Database	0.091	0.130	0.048	0.090
A.I.	0.455	0.652	0.714	0.607
Digital Library	0.455	0.217	0.238	0.303
Sum	1	1	1	1

Consistency Check		
{Ws}=[C]{W} Weighted Sum Factor	{W} Criteria Weights	Cons={WS}./{W} Consistency Vector
0.272	0.090	3.031
1.965	0.607	3.238
0.954	0.303	3.145

λ=3.138
CI= (λ-n)/(n-1) = (8.562-3)/(3-1)=.069
CR= CI/RI=.0803/0.52=0.132

AHP

Storage Capacity Comparison Norm				
	Script and Database	A.I.	Digital Library	Design Alternative Priorities
Script and Database	0.143	0.143	0.143	0.143
A.I.	0.714	0.714	0.714	0.714
Digital Library	0.143	0.143	0.143	0.143
Sum	1.000	1.000	1.000	1.000

Consistency Check		
{Ws}=[C]{W} Weighted Sum Factor	{W} Criteria Weights	Cons={WS}./{W} Consistency Vector
0.429	0.143	3
2.143	0.714	3
0.429	0.143	3

λ=3

CI= (λ-n)/(n-1) = (3-3)/(3-1)=0

CR= CI/RI=0/0.52=0

AHP

Usability Comparison Norm				
	Script and Database	A.I.	Digital Library	Design Alternative Priorities
Script and Database	0.231	0.217	0.333	0.260
A.I.	0.692	0.652	0.556	0.633
Digital Library	0.077	0.130	0.111	0.106
Sum	1	1	1	1

Consistency Check		
{Ws}=[C]{W} Weighted Sum Factor	{W} Criteria Weights	Cons={WS}./{W} Consistency Vector
0.790	0.260	3.033
1.946	0.633	3.072
0.320	0.106	3.011

λ=3.137
CI= (λ-n)/(n-1) = (3.137-3)/(3-1)=0.069
CR= CI/RI=0.069/0.52=0.132

AHP

Accuracy Comparison Norm				
	Script and Database	A.I.	Digital Library	Design Alternative Priorities
Script and Database	0.143	0.2	0.077	0.140
A.I.	0.429	0.6	0.692	0.574
Digital Library	0.429	0.2	0.231	0.286
Sum	1	1	1	1

Consistency Check		
{Ws}=[C]{W} Weighted Sum Factor	{W} Criteria Weights	Cons={WS}./{W} Consistency Vector
0.427	0.140	3.049
1.853	0.574	3.230
0.897	0.286	3.133

λ=3.039

CI= (λ-n)/(n-1) = (3.039-3)/(3-1)=0.019

CR= CI/RI=0.019/0.52=0.037

AHP

Aesthetic Comparison Norm				
	Script and Database	A.I.	Digital Library	Design Alternative Priorities
Script and Database	0.2	0.2	0.2	0.2
A.I.	0.6	0.6	0.6	0.6
Digital Library	0.2	0.2	0.2	0.2
Sum	1	1	1	1

Consistency Check		
{Ws}=[C]{W} Weighted Sum Factor	{W} Criteria Weights	Cons={WS}./{W} Consistency Vector
0.6	0.2	3
1.8	0.6	3
0.6	0.2	3

λ=3
CI= (λ-n)/(n-1) = (3-3)/(3-1)=0
CR= CI/RI=0/0.52=0

AHP

Maintainability Comparison Norm				
	Script and Database	A.I.	Digital Library	Design Alternative Priorities
Script and Database	0.2	0.2	0.2	0.2
A.I.	0.6	0.6	0.6	0.6
Digital Library	0.2	0.2	0.2	0.2
Sum	1	1	1	1

Consistency Check		
{Ws}=[C]{W} Weighted Sum Factor	{W} Criteria Weights	Cons={WS}./{W} Consistency Vector
0.6	0.2	3
1.8	0.6	3
0.6	0.2	3

λ=3
CI= (λ-n)/(n-1) = (3-3)/(3-1)=0
CR= CI/RI=0/0.52=0

AHP

Compactness Comparison Norm				
	Script and Database	A.I.	Digital Library	Design Alternative Priorities
Script and Database	0.231	0.429	0.2	0.286
A.I.	0.077	0.143	0.2	0.140
Digital Library	0.692	0.429	0.6	0.574
Sum	1	1	1	1

Consistency Check		
{Ws}=[C]{W} Weighted Sum Factor	{W} Criteria Weights	Cons={WS}./{W} Consistency Vector
0.897	0.286	3.133
0.427	0.140	3.049
1.853	0.574	3.230

λ=3.137
CI= (λ-n)/(n-1) = (3.137-3)/(3-1)=0.069
CR= CI/RI=0.069/0.52=0.132

AHP

Reliability Comparison Norm				
	Script and Database	A.I.	Digital Library	Design Alternative Priorities
Script and Database	0.2	0.2	0.2	0.2
A.I.	0.6	0.6	0.6	0.6
Digital Library	0.2	0.2	0.2	0.2
Sum	1	1	1	1

Consistency Check		
{Ws}=[C]{W} Weighted Sum Factor	{W} Criteria Weights	Cons={WS}./{W} Consistency Vector
0.6	0.2	3
1.8	0.6	3
0.6	0.2	3

λ=3

CI= (λ-n)/(n-1) = (3-3)/(3-1)=0

CR= CI/RI=0/0.52=0

AHP

Final Rating Matrix								
Selection Criteria	Speed	Storage Capacity	Accuracy	Usability	Aesthetic	Maintainability	Compactness	Reliability
Script and Database	0.090	0.143	0.140	0.260	0.2	0.2	0.286	0.2
A.I.	0.607	0.714	0.574	0.633	0.6	0.6	0.140	0.6
Digital Library	0.303	0.143	0.286	0.106	0.2	0.2	0.574	0.2

{W} Criteria Weights
0.218
0.099
0.036
0.123
0.333
0.051
0.099
0.041

Concept	Alternative Value
Script and Database	0.184
A.I.	0.571
Digital Library	0.245